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Forest Service

APPALACHIAN FOREST EXPERIMENT STATION

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AN EYE-TEST FOR LOOKOUT MEN

By

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The following was published in Fire Control Notes (4: 123-128. July 1940) essentially as it appears here. Because reprints are not available to meet frequent requests from military and forest-fire protection personnel for information on the eye-test, the article is being republished as a Technical Note. Some additional information on later field trials is included.

The efficiency of a forest-fire lookout man depends mainly on four qualifications: (1) experience, (2) knowledge of his territory, (3) alertness, and (4) quality of his eyesight. A man's rating on the first three factors can be judged with reasonable accuracy, but some sort of measurement is necessary to determine his rating on the fourth.

The importance of eyesight can be shown by considering possible advantages to be obtained by manning a lookout network with individuals having keen eyesight. These advantages are: (1) an increase in the visual range of small smokes and (2) shorter discovery times for smokes within the visual range. A lookout station network with men of keen eyesight, compared to a network with men of normal eyesight, other qualifications being equal, might be regarded as giving more protection for the same amount of money or, by using fewer men, the same protection for less money.

In 1932, the writer assisted in developing a preliminary eye-test at the Pacific Northwest Forest and Range Experiment Station for measuring the ability of lookout men to see small smokes.1/ That test was developed

1/McArdle, Richard E. and George M. Byram. An eye-test for fire lookouts. Jour. Forestry 34: 794-796. August 1936.

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for another purpose but subsequently was used by the Forest Service for testing the vision of lookout men. When carefully given under uniform lighting conditions, it gave good results, but it is now replaced by the test described here. The design of a vision test, like the design of any other tool, depends on the uses for which it is made. The test described here is designed to measure the ability of an observer to see small individual objects on backgrounds which are fairly uniform in brightness. If an observer is required to resolve minute details, then a resolving power test, such as a series of parallel lines on a uniform background, or even the usual letter-type chart, would perhaps be more suitable.

An eyesight test for forest lookout men, developed at the Appalachian Forest Experiment Station, meets the following essential requirements: (1) gives ratings proportional to the distance at which lookout men can see small smokes, (2) gives ratings the values of which are independent of light intensities, and (3) is sufficiently simple for field use.

The new test consists of measuring the distance at which an individual can see a black circular spot 1/16 of an inch in diameter on a white background about 7 inches square. The eye-test pattern (Figure 1) is printed on glossy white photographic paper by means of a master negative and is cemented to stiff, inflexible backing. (Complete specifications for the lookout eye-test target are given on page 10.) The 1/16-inch black dot is located on a diagonal of the eye-test board or target half-way between a 1/4-inch central black circle and the end of a black bar at the corner of the diagonal. The corner bars and large center circle serve only as markers which enable the observer to know where to look for the small black circle.

The test can be given most satisfactorily on a day when the sky is overcast, but equally good results can be obtained on a sunny day if the target is shaded from the direct rays of the sun. In any event, the target should not be in deep shade such as occurs directly under a tree, but should be exposed to the full light of the open sky.

In taking the test, the observer walks away from the eye-test board until the 1/16-inch black spot becomes rather faint. This usually happens at about 35 or 40 feet. The eye-test board is then whirled so that the small black spot is in a new position, which may be up, down, right, or left. The observer then indicates the position of the spot, and if correct, he steps back a few feet and the procedure is repeated until he indicates a false position of the spot. His rating is then recorded as the distance in feet to the last point at which he indicated correctly the position of the black spot. (Detailed instructions appear on page 9.)

The small black spot becomes more indistinct as the observer moves farther away, but he should continue to guess its position even though he lacks confidence in his ability to do so correctly. Some individuals wish to rest their eyes between observations, although prolonged looking does not seem to change a man's rating.

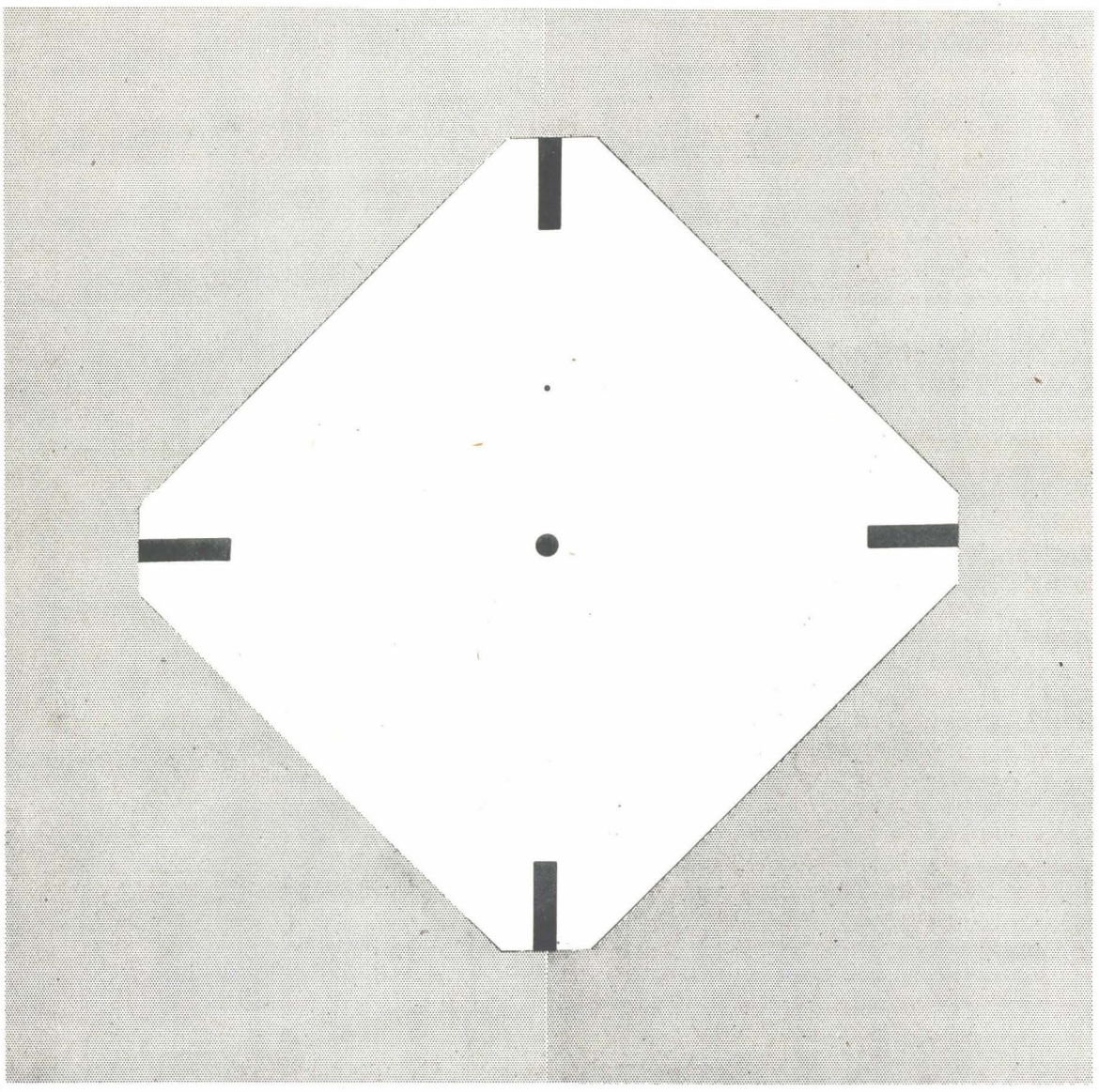

Figure 1.--Lookout eye-test pattern (approximately one-half actual size).

Figure 2 shows the effect of light intensity on the visual range of three different types of eye-test targets. Light intensity is expressed as brightness of the white component of the target in candles per square foot. Curve A is plotted from observations made with the new eye-test board under various light intensities. Only at very low brightness levels are the ratings seriously affected. For this reason the test should always

be given out of doors, where even on rather dark, cloudy days the brightness level is high enough (about 75 candles per square foot for a white surface) to give reliable ratings. On the other hand, the target should not be in direct sunlight (about 800 candles per square foot for a white surface) or ratings will be slightly lowered. Curve B shows the relation between brightness and the visual range of a 1/16-inch white spot on a black background. The visual range of the white spot is considerably affected by light intensity. Curve C is a similar curve for a white spot on a grey background. This type of target would also be suitable for a lookout eye-test but it is difficult to construct so that the white and grey components will always have the same brightness ratio.

Figure 2 also shows that the target combination of black on white satisfies the second requirement for a lookout eye-test. That this combination also satisfies the first requirement was determined in three different ways:

(1) Tests were made on actual smokes with men of known but different eye-test ratings. This was the most direct but least satisfactory method of determining whether the eye-test met the first requirement. The results of five tests on seven men showed that men who rated poor on the test could not see smokes as far as men who rated average, and men who rated average could not see smokes as far as men who rated good or exceptional. To obtain actual quantitative relations between eyesight and smoke-seeing ability by this method would require hundreds of tests and the results probably would not be as reliable as the more indirect laboratory methods.

(2) An observer with normal eyesight simultaneously viewed a smoke-like target and the lookout eye-test target with his vision normal and then with his vision impaired in some way, such as by using glasses with strong convex lenses, or by viewing the targets through small diaphragms. In this way it was possible to duplicate various visual defects and yet have all observations made by one man. The results showed that the visual range of both types of target was reduced in almost the same ratio by any given visual defect.

(3) Mathematical calculations of the actual form of retinal images showed that the form of the image of a small smoke on a distant landscape is similar to the image of a small target (either black or grey on white, or white on grey).2/

Figure 3 shows the relation between ratings of different men, obtained with the new lookout eye-test and with the usual letter-type charts used by oculists. Ratings were plotted against the maximum distance that each

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2/Byram, George M. The physical and photochemical basis of visual resolving power. Manuscript accepted for publication by Jour. Opt. Soc. Amer. 1944.

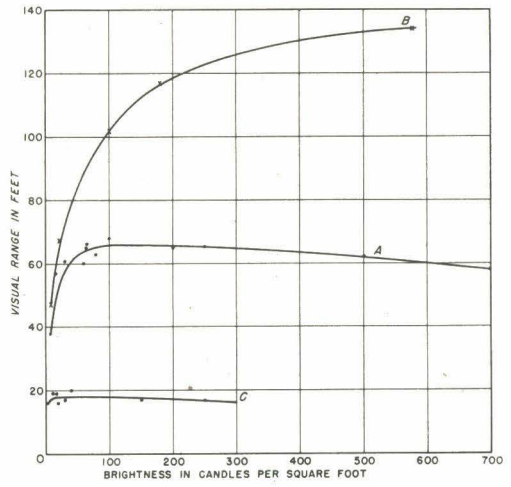

Figure 2.--The visual range of three different target-background combinations plotted against the brightness of their white components. Curve A, black on white; Curve B, white on black; Curve C, white on grey.

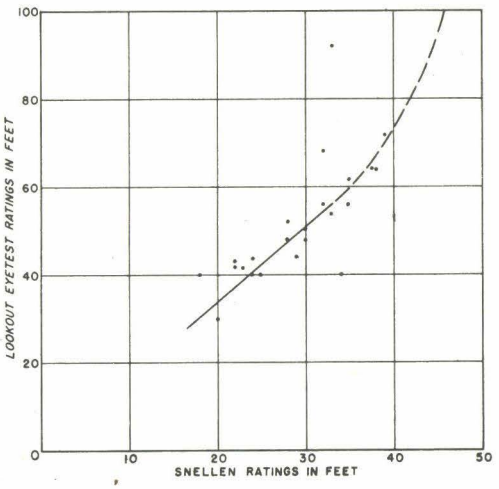

Figure 3.--Ratings obtained with the lookout eye-test plotted against ratings obtained with 3/10-inch letters on the Snellen chart.

man could read 3/10-inch letters on the Snellen chart. This curve indicates that the letter-type chart could be used for determining poor or even average eyesight, but would not show which men have exceptionally good eyesight ("eagle eyes"). The reason for this is that the visual range of small letters which can just be read is affected by any factor which obscures detail, and for men with poor eyesight the most important factors are structural defects in the eye and lack of retinal sensitivity. The visual range of the eye-test target is affected by these factors in a corresponding manner, so a linear relation is obtained for the lower part of the curve when the visual range of small letters is plotted against the visual range of the eye-test target. However, individuals with exceptional eyesight probably have highly sensitive retinas and few defects in the structure of their eyes. The visual range of small letters for these men will be limited chiefly by the wave-length of light, and there is a definite limit to the distance the letters can be read, no matter how good the observer's eyesight. There is no definite physical limit to the visual range of the black spot on the eye-test target or the visual range of a small smoke. Retinal images of these objects are affected differently by diffraction than are the retinal images of letters.

The data plotted in Figure 3 are not sufficient to determine whether that portion of the line shown as dotted should curve upward. That this must be true can be found from calculating the angular limit at which the details of the letters can be recognized. For the 3/10-inch letters used in this test, this limit comes at about 60 or 65 feet. No matter how keen a man's eyesight, he will not be able to recognize the letters at distances greater than this, hence the curve should turn upward and approach the 60- or 65-foot limit as an asymptote.

The letter-type test should give fairly accurate results for about 70 percent of the men tested. It probably would not be accurate for the upper 30 percent, and since there is a definite limit to the distance at which a letter of a given size can be recognized, the letter test would be inaccurate for the upper 5 percent or "eagle-eyed" individuals. The letter-type test has other drawbacks:

(1) Men familiar with letters can recognize them at slightly greater distances than men who are not familiar with them. The visual range is affected by the "degree of literacy."

(2) Different letters of the same size are not equally visible.

(3) The letters on any one chart can be memorized.

Table 1 shows the visibility distance of a small standard smoke for various eye-test ratings and haze-meter readings. It can be seen that large variations in eyesight cause much smaller variations in the visual range of smokes. This might indicate that a man who rated high on experience, alertness, and knowledge of his territory would perhaps make a good lookout even though his eyesight were no better than average. A new man, or a man who rated only average on the qualifications just listed, should perhaps have better than average eyesight. With the figures of Table 1 available to him, the judgment of an experienced fire man on this point might be more effective than any set rule as to how good a prospective lookout man's rating should be to qualify for detection work.

Table 1.--Visibility distance of a small smoke (miles)

Eye-test rating	Haze-meter readings							
	2	4	6	8	10	12	14	16
72.....	3.8	6.2	8.2	10.0	11.6	13.0	14.3	15.7
64.....	3.7	6.0	7.9	9.6	11.1	12.5	13.8	15.0
56.....	3.5	5.8	7.6	9.2	10.6	11.9	13.1	14.3
48.....	3.4	5.5	7.2	8.7	10.0	11.3	12.5	13.5
40.....	3.2	5.2	6.8	8.2	9.4	10.6	11.6	12.6
32.....	3.0	4.8	6.3	7.6	8.7	9.7	10.7	11.6

Table 1 appears to contradict the statement that the distances at which lookout men can see small smokes are proportional to eye-test ratings. However, this is not so, because the figures in Table 1 have been corrected for the difference in atmospheric haze between the distances corresponding to the high ratings and the distances corresponding to the low ratings. If one man has an eye-test rating of 60 feet and another man a rating of 50 feet, then the first could see a smoke column 6 miles when the second could see it only 5 miles, provided both men were looking through the same amount of haze. However, in actual practice the man who has a high rating will have to look through more haze and this will reduce his superior range of vision, which tends to bear out the statement that of all factors affecting the visibility of small smoke columns, haze is the most important.

Table 2 gives average ratings for several groups of men, 164 individuals in all. As a class, the relief workers rated considerably lower than other classes, and it was assumed that diet was largely responsible for this low rating.3/ Great variation in eye-test ratings exist within each group. For example, among the 110 Army men one individual could see the small test spot 80 feet but another man only 20 feet. The frequency distribution of eye-test ratings approaches the normal curve and if this relation holds for high readings, about 1 man in 3,000 should be able to see the small spot consistently at 90 feet.

Table 2.--Average eye-test ratings for five different groups of men

Class	Number of men	Average rating in feet
CCC enrollees	15	55.5
Regular Forest Service personnel	19	57.0
College students	11	54.3
WPA relief workers	9	43.4
Enlisted men, U. S. Army	110	50.9
Weighted average		51.8

Standards or classes of performance are shown in Table 3 for various distance ratings in feet. The approximate relative smoke-seeing ability corresponding to each class is also given. For purposes of comparison, atmospheric conditions are assumed to be such that a man with average eyesight could see a small smoke 10 miles away.

3/Byram, George M. Vision and diet. Service Bull. (U. S. Forest Service) Washington, D. C. February 5, 1940.

Table 3.--Tentative standards of performance and relative smoke-seeing ability for different class intervals of eye-test distance ratings

Eye-test rating in feet	Performance rating	Relative smoke visibility rating in miles
64 or more.....	Exceptional.....	11.0 or more
58-63.....	Good.....	10.5
50-57.....	Average.....	10.0
44-49.....	Fair.....	9.5
43 or less.....	Poor.....	9.0 or less

During recent tests by Hayes and Byram[4/] with a group of 110 Army enlisted personnel, it was observed that men who could see the spot at exceptionally long distances (65 feet or more) would usually see it much more quickly at short distances than men of only average visual powers, even when the "short" distance was well within the visual range of each. This indicates that small objects, including small smokes, which are not readily obvious to most eyes, can be perceived or "seen" quicker by "eagle eyes" than by ordinary eyes. It seems logical, therefore, that a man who rates exceptionally high on the lookout eye-test might detect, while rapidly scanning an area, an indistinct smoke that an average man would not see without slow and careful study.

When the stimulus of competition made the men eager, so that they tried hard, they could see the spot farther than when "just looking." They were tested in groups of 10 to 15. The first few in each group usually showed but little interest in the test and exerted little effort to see the spot. After someone had made an unusually high score, however, a spirit of competition would seize the group and many of those first tested would try again and be able to see the spot as much as 10 or 15 feet farther than they had on their first trial. Evidently visual performance, like muscular or mental performance, can be stimulated and increased by effort.

Of the 110 men tested, all from a field artillery observation battalion, a group of 13 experienced observers could see the spot an average of 10 feet farther (20 percent) than the group as a whole. This is believed to indicate that ability to see small objects can actually be increased by experience and practice.

Show and others[5/] have pointed out the need for eye-tests, stimulation through competition, and experience to obtain maximum performance from forest-fire lookouts. These observations further emphasize the need

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4/Hayes, G. L. and George M. Byram. The effects of good visual powers, effort, and practice on seeing. Jour. Forestry 42: 53. January 1944.

5/Show, S. B., E. I. Kotok, George M. Gowen, J. R. Curry, and A. A. Brown. Planning, constructing, and operating forest-fire lookout systems in California. U. S. Dept. Agr. Cir. 449. 1940.

INSTRUCTIONS FOR USE OF EYE-TEST FOR FIRE LOOKOUT OBSERVERS

The eye-test is a device designed to measure the relative ability of lookout observers to see small smokes. The eye-test apparatus consists of a square white board with a large black spot in the center, black bars on the diagonals, and a small black spot midway between the center and one diagonal bar. The maximum distance that a man can see this small spot is a measure of his power to see small columns of smoke at long distances. The eye-test is given as follows:

Insert the round peg in the block on the back of the board to form a handle. Select a suitable place out-of-doors. Either a sunny or cloudy day will do. A dark foreground, such as green grass or earth, is necessary. Avoid bright foregrounds, such as dusty or graveled roads.

Hold eye-test board in full light of open sky but shaded from direct rays of sun. Avoid getting under eaves of buildings or tree crowns.

Hold eye-test board vertically so that one diagonal black bar is vertical, the other horizontal (that is, the small spot will be up, down, to right, or to left) with white side of eye-test board facing toward person being tested.

Have man being tested back away from eye-test board until small black spot almost disappears (usually 35 or 40 feet). He should not face sun.

Whirl eye-test board several times so the small black spot may assume a new position, either up, down, right, or left. Have observer signal or state new position of the small spot. If correct, have him step back 2 or 3 feet. Repeat procedure until the observer indicates position of small black spot incorrectly. Have him guess when he is no longer certain. He may rest his eyes if he wishes.

Record the observer's rating as the distance in feet from eye-test board to the last point from which he can indicate position of the small black spot correctly. The distance at which this small spot can be seen is definitely related to the distance at which small smoke columns can be easily detected. The following tabulation indicates quality of eyesight for smoke detection purposes.

Maximum distance, in feet, at which small black spot can be seen	Quality of eyesight
64 or more	Exceptional
58-63	Good
50-57	Average
44-49	Fair
43 or less	Poor

SPECIFICATIONS FOR EYE-TEST TARGET FOR FIRE LOOKOUT OBSERVERS

The following specifications, if closely adhered to, constitute a tested method for constructing eye-test targets:

Eyesight-test target to consist of a black and white pattern mounted on a 7.0-inch square back, in the center of which is mounted a handle for rotating the target.

The eye-test pattern to be printed from a brass master negative[6/] on double-weight, contrasty (No. 4 or 5), smooth, glossy, photographic paper. The brass negative must be placed with the upper or beveled surface away from the paper when prints are made.

The eye-test backing material to be hard fiber board (Masonite tempered Presdwood or equal, not plywood) of about 1/8-inch thickness, varnished lightly on both sides.

After varnish is thoroughly dry, pattern to be cemented with thin shellac to smooth side of fiber board back. Shellac has a tendency to soak into the print; therefore, the back of the print should first be sized with a dilute glue or casein solution.

Both print and fiber board back to be at least 8 inches square to insure good contact around the edges of the pattern, and to allow space for trimming. Eye-test board to be trimmed on black-white border to leave smooth edge. Corners to be trimmed.

A square or circular block, about 1-1/2 inches in diameter and 3/8-inch thick, and drilled through the center to receive a 5/16-inch dowel handle 3 inches long in a tight fit, is to be glued to center of eye-test back. Handle is not to be glued in block.

A small black spot is to be painted on back of eye-test target directly behind the 1/16-inch spot.

Instructions for use of eye-test are to be printed or pasted on front of an envelope 7-1/2 by 10-1/2 inches, in which eyetest is kept when not in use.

6/Specifications for making this master negative are on file at the Appalachian Forest Experiment Station, Asheville, N. C. Negatives will be loaned on request.